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Hilppö, Jaakko

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"Failure is just another try": Re-framing failure in school through the FUSE studio approach

Jaakko Hilppö[a,*], Reed Stevens[b]

[a] University of Helsinki, Finland
[b] Northwestern University, United States

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ABSTRACT

In an era of high-stakes testing and performance demands that regulate future educational opportunities and affect how schools are managed and funded, failure can easily become stigmatized in the practices of schooling. In turn, it can lead students to avoid activities in which they can be evaluated as failing. As researchers, if we wish to help students recognize the value of failure in the process of learning and to capitalize on failures as significant learning opportunities, we must find ways in which failure at school can be reframed as something productive, rather than punitive. In this study, we investigated how student experience in a FUSE Studio—an alternative infrastructure for learning in schools organized around principles of student choice and interest (Stevens et al., 2016)— support a different, more productive 'use' of failure. Our study is an investigation of how failure was framed in the FUSE Studio by students and teachers and whether these participants recognized learning from failure as a productive part of their FUSE Studio experience. Our analysis, which was based on a year-long video ethnography conducted in a typical FUSE Studio, revealed two distinct ways in which failure was framed. In addition, an analysis of participant interviews highlighted that the students and a facilitator viewed failure as a significant and productive part of their FUSE Studio experience. In sum, the study contributes to the existing literature on the value of failure for learning, by highlighting a way that failure can be framed as being productive for both students and teachers.

1. Introduction

"I have not failed. I've just found 10,000 ways that won't work" is a widely-cited quotation associated with Thomas Edison, one of the great North American inventors. Although the quotation is not entirely accurate (see Dryer & Martin, 1910/2010Dryer & Martin, 1910/2010; TAE, 2012), its reframing of failure nonetheless highlights the value and necessity of 'failure' in innovation-oriented activities. These aspects of failure have been recognized in the literature on learning and creative practice in various fields (e.g., Firestein, 2015; Petroski, 1985; Isaacson, 2011; Juul, 2013). Recently, researchers have begun to highlight the importance of failure not only in the lives of famed inventors and innovators, but also in the learning and professional practice of science, technology, engineering, and mathematics (STEM) professionals and artists (Ventura, Shute, & Zhao, 2013; Simpson & Maltese, 2016; McCarthy, Sullivan, & Wright, 2006; Klemp et al., 2008).

The role of failure in learning has also received increased attention among educational researchers. Investigations of its impact have demonstrated ways in which failure can be beneficial to learning in conventional academic courses (Kapur & Bielaczyc, 2012;

* Corresponding author at: Faculty of Educational Sciences, University of Helsinki, P.O. Box 9, 00014, Finland.
E-mail address: jaakko.hilppo@helsinki.fi (J. Hilppö).

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Kapur & Rummel, 2012; Kapur, 2008; Manalo & Kapur, 2018; see also Tan, Lee, & Ng, 2017). In these studies, researchers have tried to show that failure can be productive if students attempt to solve curricular problems that are beyond their abilities, even if they are ultimately not able to solve them—and if their attempts are followed by consolidating instruction. The authors have shown that this two-phase model can lead to better short and long-term learning gains in a content area when compared to with models through which the instruction precedes problem solving or when the students try to solve problems without any instruction (Kapur, 2008, 2010). While these findings are important indicators of the value of failure for learning, they explore a reframing of failure in traditionally organized curricular subject area experiences. In contrast, the focus of this study is on failure in more open-ended, student-directed making activities, a focus that has recently been taken up by other researchers also. For example, Gomoll, Tolar, Hmelo-Silver, and Šabanović (2018) study of teachers' social scaffolding in an open-ended, making-oriented environment showed how teacher scaffolding helped failure become a learning resource for students as they designed and re-designed robots (see also Maltese, Simpson, & Anderson, 2018). Estabrooks and Couch's (2018) discourse analytic study showed that students who had engaged in creative invention activities came to value failure as an integral part of their inventing activities, as opposed to a negative outcome. Together these and other similar studies have begun to explore how failure can be reframed in designed learning environments and that such reframing can impact how students come to see failure anew—as something generative and productive for their learning.

While these studies suggest a growing awareness of the potential value of failure in learning, the perceptions and consequences of failure in most schools remain stubbornly resistant to change. It has been suggested in some research that even in a standard instructional context, learning opportunities can be realized through uses of students' incorrect answers (e.g., Chin, 2007), but that perspective notwithstanding, students are seldom invited to appreciate or analyze the feedback that failure offers. School work and assessment practices are mostly geared towards attaining and routinizing effective problem solving for standard problems within classroom cultures that do not easily allow for revisiting problems or their alternative solutions. In students' experiences, these practices frame failing as a hindrance at best, as something that slows their pace of work and prevents them from moving forward either individually or collectively. In addition, for students, the issue of failure extends beyond the academic focus of classroom instruction to other parts of the school day experience. The ways that mistakes or accidents are treated—such as in the lunchroom, hallway, or during recess—also contribute to how students view failure (Spaulding, 1997; Smyth, 2007).

In their book, *Successful Failure: The School America Builds*, Varenne and McDermott (1999) offered a notable analysis of how failure is produced and understood in American schools. They argued that failure, and its counterpart success, "are categories, scripts, and stage directions that frame joint human action" (1999, p. 10). They argued that in American schools this is done in ways that ascribe and attach failure (or success) to individuals as a personal quality rather than as a collective production, often with the tacit goal of sorting students, teachers, and schools into winners and losers: those most American of binary categories. For our purposes, one of their empirical chapters most relevant to our study (Chapter 5) reports on "children performing well in a prosperous suburban middle school". However, even here, the authors show that "*[f]or the most part, successful children are rarely more than one step ahead of failure: A quiz here or there, a bad day on the SATs, a behavioral blemish on their record—just about anything can knock them off their chosen paths, or at least that is what they are constantly told. There is rarely a moment for them to let down their guard. Failure is always possible, always imminent, always immediately around the corner. They are rarely allowed to forget failure, and they work hard avoiding it. Still, their repeated failures may not be too consequential either, since there are others, in other classes and other schools, who will be known as having failed worse"* (Varenne & McDermott, 1999, p. xii). Against the backdrop of this image, of failure always lurking "immediately around the corner," we ask: could failure be reframed in schools—even if only in islands of particular classrooms—so that failure is no longer a threat but that it becomes a resource for learning?

In this paper, we offer evidence that the FUSE Studio approach can offer a powerful site for the reframing of failure in classroom. In the following sections, we proceed first by explaining the FUSE Studio approach and how we have operationalized failure as "just another try." After this, we present evidence from a year-long video-ethnographic research study carried out in a typical FUSE Studio and an analysis of how student and teacher participants oriented to failure within the FUSE Studio environment. We then share two examples of how failure was framed differently in the FUSE environment than it typically is in classrooms. We provide evidence from student and teacher interviews to show that the reframing was a significant and recognized part of the FUSE Studio experience for the participants. We also touch upon the question of how teaching, or what we call 'facilitating,' in a FUSE Studio can impact a teacher's perceptions of her students' capacities and their ability to succeed, or rather, successfully fail.

2. What are FUSE Studios?

The FUSE Studio is a model for an alternative learning infrastructure in schools (Stevens et al., 2016). A key goal of FUSE Studios is to act as an entry point or 'on-ramp' for students to discover and develop new interests—or further develop existing interests brought from out-of-school pursuits— through activities in what have come to be called STEAM areas (i.e. science, technology, engineering, arts, and mathematics.) The aim of the FUSE Studio model is to develop students' collaboration skills, creativity, critical thinking, and other related competencies associated with the broad notion of 21st century skills. The core activities of FUSE revolve around a suite of about 30 STEAM *challenges* that students and facilitators access through a website. The challenges are arranged in sequences that 'level up' like video games. After a student completes a level in a sequence, the student uploads a digital artifact demonstrating completion of the level and that unlocks the next level. The next level is designed to be more difficult or complex and builds on the skills that were needed in the prior level in the sequence. The challenges range from building solar cars, laser mazes, and roller coasters, to designing and printing 3D jewelry, coding video games, and designing houses with 3D modelling software. In each challenge, the students work step-by-step on an artifact that they design and create by completing the level (e.g., a 3D printed

keychain or a ring tone for their phone). Some of the challenges are completely digital, while others require students to use tangible materials provided to them in kits. In addition to challenge instructions, the FUSE website offers the students help resources in the form of video tutorials, images, and links to other websites.

Learning from failure is a core design principle of the FUSE Studio model. From its inception, a key FUSE motto has been "failure is just another try". The basis for this principle was ethnographic research by the second author and colleagues into young people playing video games in their own homes (Stevens, Satwicz, & McCarthy, 2008), as well as prior conceptualizations about the productive qualities of video games as learning environments (e.g. Gee, 2007). In game play, players try to beat a level and if they don't, they will typically try again and try differently if they find the game interesting. And because players can 'fail' without dire consequences (e.g. like bad grades that have negative and largely irreversible social impacts), failure is accepted as part of the process of learning to play. In FUSE, when players fail to complete a level, they can simply try again.

A closely-related design principle of FUSE, and perhaps its central principle, is choice. Students in a FUSE Studio choose the challenges they work on, their pace of work, when to stop working on the challenges and whether to work alone or with others. Coupled with the principle of allowing 'failing' a challenge not to be attached to negative consequences, students tend to persist when they choose a challenge they like, even when they find it frustrating and difficult. In research interviews, FUSE student participants often talk about FUSE challenges being *both* fun and hard. Another related design principle is that challenges are designed with clear attention to what young people find interesting. There are challenges about making ring tones for your phone, designing your dream home, and making wearable jewelry or clothing with electronic elements. All these design principles are meant to work synergistically to convey to students that they are in a very different, and hopefully more compelling, learning environment than typical courses.

Previous research that we and our colleagues have conducted on FUSE Studio implementations has shown that the FUSE Studio approach generates common phenomena in a range of classrooms that constitutes both an alternative infrastructure and a palpably different learning culture from traditional subject matter classrooms (Stevens et al., 2016; Ramey & Stevens, 2018). Furthermore, our more recent efforts have begun to demonstrate that the FUSE Studio model is stable, sustainable, and can be implemented with integrity across a wide variety of school settings and with adapted variations of the core model (Stevens et al., 2018).

In this article we explore a general question that has not previously been explored in depth—the way in which the design principle of "failure is just another try" reframes failure for students (and teachers) in FUSE Studios. Our investigation was guided by the following three more specific research questions:

1 How do the participants frame failure through their actions in the FUSE Studio?
2 How do participants recognize learning from failure and persistence as significant parts of their FUSE Studio experiences?
3 How do the interactions in the FUSE Studio impact the teachers' perceptions of their students, if at all?

3. Data set and analysis

During the 2015–2016 academic year, we collected video ethnographic data from seven FUSE Studio implementations in three schools located in a large Midwestern school district in the USA. In each FUSE Studio, 5th and 6th grade students worked for 90 min per week on FUSE for most of a school year as part of their science curriculum, with the homeroom teacher acting as the facilitator. At the time of our data collection, the 6th graders had already worked in a FUSE Studio for a year as 5th graders and their teacher had a prior year of experience facilitating a FUSE Studio. The implementation of FUSE in the school district had started in 2013 and by the start of the 2016-17 school year, had spread from the first implementing schools to 25 additional schools, reaching all 5th and 6th graders in the district.

In this paper, the focus of our analysis is on one of the seven FUSE Studios we studied. This was Susan's FUSE Studio (all participant names are pseudonyms), which was a typical FUSE Studio according to our observations. That is, Susan's studio was well-aligned with the design principles of the FUSE Studio model but did not stand out when compared to the other six studios or to other FUSE Studios around the US. For example, the completion rate for challenges for students in Susan's studio was only slightly above the national average. Also, the ways in which students engaged with the challenges were also like the other studios (DiGiacomo et al. submitted; Ramey, 2017). In addition, Susan's studio culture featured many of the phenomena we had observed in other studios, such as a dynamic peer learning and teaching community, students learning in diverse and productive learning arrangements, and students often going 'off road', extending challenge work into new directions (Stevens et al., 2016).

Our data collection in Susan's FUSE Studio, as in all seven studios, proceeded in the following ways. At the beginning of each studio session, we asked seven students to wear a 'visor camera' while they worked. A visor camera is an action camera attached to the visor of a cap and this allowed us to follow their activities from their perspectives as they moved about in the Studio. The number of students who could wear a camera during a single session was limited by the number of cameras available to us. To ensure that the students were comfortable in wearing the visors and sharing their work with us, it was also possible for them to say "no" to wearing the visor. We collected visor camera data from 14 out of the 23 students and Susan the teacher. A wide-view video camera was also positioned at the back of the studio to capture the broader movements of the entire studio. In all, we collected about 55 h of video data from Susan's studio. In addition, we collected field notes, did impromptu interviews and took photographs of the digital and tangible artifacts students made during the sessions. At the end of the year, we conducted semi-structured interviews with Susan and eight students, from whom we had substantial visor camera material. The goal of the interviews was to allow the students and the teacher to share their perspectives on their experiences over the year in the FUSE Studio.

3.1. Analysis

To answer our first research question, our analysis proceeded in two iterative phases. To keep our observations focused on the participants' perspectives on failure, in the first phase of our analysis, we selected four potential student cases that seemed to have rich examples of failure in FUSE Studios. These cases were selected according to our fieldnotes, prior case studies from Susan's studio, and the studio web data. The selected students did not stand out from the other students in Susan's studio in any other way. We then constructed person-centered ethnographic accounts (Stevens et al., 2008) of these four cases which detailed the challenges the students worked on during the year and how their work had progressed during the sessions. Importantly, we paid special attention to whether a student failed during their work. In practice, this involved highlighting episodes from the video data in which a student attempted to complete a task related to a challenge (i.e., 3D printing of an artifact) but failed. After reviewing such episodes along with the other members of our research team, the second phase of the analysis began. During this phase, we used interactional analysis methods (Hall & Stevens, 2016; Jordan & Henderson, 1995) that focused on how the participants handled failures and eventually resolved them during these episodes. We transcribed the verbal, non-verbal, and material conduct of the participants during the episode by following a modified Jeffersonian transcription notation (Jefferson, 1984), and then used these transcripts to further analyze the interactions. These episodes were then compared with other examples of failure in Susan's studio.

For the second and third research questions, we conducted a content analysis (Cohen, Manion, & Morrison, 2007) of the student and teacher interviews. We read through the interview transcripts multiple times and identified the different ways the participants discussed their experiences in the FUSE Studio over the year. Next, we focused specifically on how the students described their experiences in relation to failure in the FUSE Studio and examined whether they held or developed views that failure could be productive to their learning or activities in the studio. From Susan's interview, we also looked for how she talked about failure in her studio and the value she placed on failure, if any, as well as if there was any indication that her relationship to her students had changed or if she perceived them differently after facilitating the FUSE Studio.

4. Results

The results of our study showed that the students and teacher treated failure as an ordinary feature of the studio culture. The results also revealed that persisting with the challenges and learning from failure, were significant in the experiences of the students and the teacher in the FUSE Studio. Furthermore, for Susan, the teacher, the interactions with her students in the FUSE Studio did bring out new aspects of some of her students to her. Detailed results, with examples, are presented in the following sections to answer each research question.

RQ1. How do the participants frame failure through their actions in the FUSE Studio?

In relation to our first research question, we identified two ways in which failure was framed in the FUSE Studio. In both, failure was observably a participant's concern (Stevens, 2010) but came to be treated in two different but productive ways. First, failure was treated as a prosaic moment while working on a challenge. Second, failure set in motion investigations by the students into an in-depth analysis of the source of failure. According to our analysis, both ways were common to how failure was treated in Susan's studio.

4.1. Example 1 Getting the cut depth right

In the first example, three girls in 5th grade, Koyana, Prisha and Aiesha, encountered an issue when attempting to print a sticker in a challenge that asked them to use a vinyl cutter to print a layered sticker of their own faces. This challenge is called "Selfie Sticker" and the first level of this challenge asks students to create a simple sticker design (such as their name), to convert it into a vector graph, and then to instruct the computer-operated vinyl cutter to cut the design (see Image 1 for level one challenge progression). During this episode, Prisha helped Aiesha print her level-one sticker—the word cupcake—and Koyana assisted Prisha. The episode took place during their 16th FUSE Studio session during the November of 2015. By that time, Prisha had already worked on the challenge for the last six sessions and had completed level one a week before. Koyana and Aiesha had not worked on the challenge directly prior to this but had observed Prisha complete the challenge.

At the beginning of the class session, Koyana, Prisha, and Aiesha set up the vinyl cutter and the other challenge materials. After measuring and cutting a piece from a large roll of green vinyl, the girls gathered around the vinyl cutter. Prisha set up the cutter and the materials, Aiesha looked over as Prisha worked, and Koyana waited by the computer for instructions from Prisha. After a moment of waiting, Koyana said that Prisha should *"put it on eight, just like we did,"* which was a suggestion to use the same blade depth they had used for Prisha's sticker before.

After checking the depth, Prisha started the vinyl cutter, and the girls closely observed as the machine worked. While waiting, they commented on the sticker's progress, and Koyana and Prisha recalled how they had used the same cutter depth during the previous printing session (Fig. 1, turn 23-25. Transcripts simplified for better readability). Then, Koyana told Prisha that the blade was not deep enough, meaning that the sticker would not print correctly (turn 25). Prisha stopped the machine and closely examined the vinyl. While Prisha inspected the vinyl, Koyana suggested that they should change the depth to nine (turn 33). Prisha agreed and proceeded to make the adjustment (turn 34–35).

After a second attempt with the same piece of vinyl, the girls realized they needed a new piece of vinyl. They cut it out and returned to the vinyl cutter. They proceeded in the same way as before with Aiesha looking over, Prisha operating the vinyl cutter,

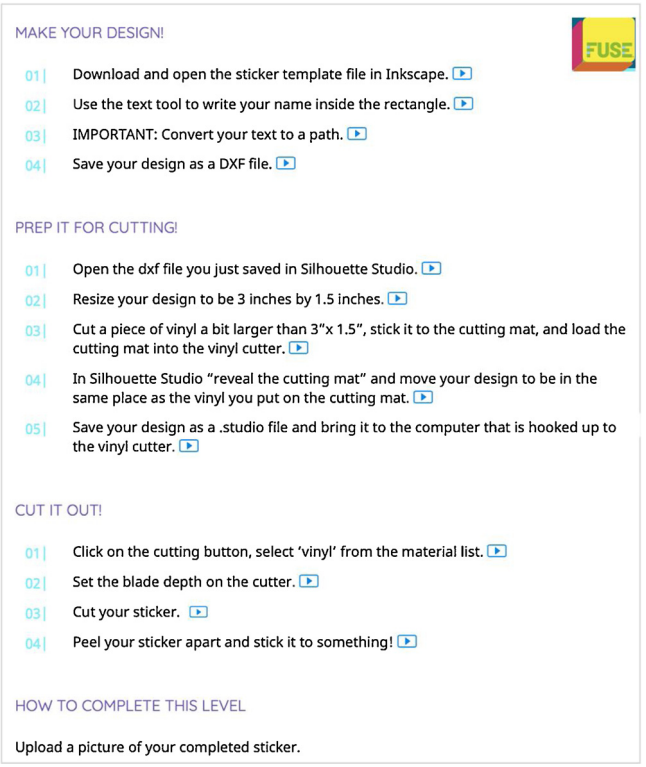

Image 1. Selfie Sticker Level 1 instructions.

Turn	*Speaker*	*Turn-at-talk / action*
23	Prisha:	Which was on our last one? Which number was that?
24	Aiesha:	Seven.
25	Koyana:	No, last time we did eight. It's not down all the way Prisha.
26		Prisha stops the cut.
27	Prisha:	(unclear)
28	Koyana:	Wait.
29	Prisha:	I'm gonna unload it wait wait wait wait
30	Koyana:	(unclear)
31	Prisha:	Cut it.
32		Cutter unloads. Prisha grabs the vinyl.
33	Koyana:	We should put it on nine.
34	Prisha:	Yeah.
35		Prisha adjusts the cutter.

Fig. 1. Changing depth.

Turn	*Speaker*	*Turn-at-talk / action*
66	Koyana:	We had to use ten.
67	Susan:	To how deep?
68	Koyana & Aiesha:	Yeah.
69	Aiesha:	Is it 'cos we emm…
70	Susan:	Why do you think?
71	Aiesha:	We tried it.
72	Koyana:	A different piece.
73	Susan:	It seems like it's a little fickle in that sense.
74	Koyana:	Mmmm.
75	Susan:	What happened here with the C? Are you guys making sure you put it like the… making sure that this grabs this stuff?
76	Koyana & Aiesha & Prisha:	Yeah, yeah.
77	Susan:	But you problem solved and you got to the ten. Isn't that a good thing?
78	Koyana & Aiesha & Prisha:	Yeah.
79	Susan:	You didn't give up!
80	Aiesha:	No.
81	Susan:	So, sometimes it likes ten, sometimes it likes seven, sometimes it likes… it probably just depends.

Fig. 2. Showing to Susan.

and Koyana waiting to start the cut. This time, the sticker was printed correctly.

Once the print was ready, Koyana took it to their teacher, Susan, and showed her their work. Prisha and Aiesha followed close behind. Koyana told Susan that they had to adjust the cutter depth to ten (Fig. 2, turn 66). After Koyana and Aiesha clarified the depth to Susan, Aiesha asked for Susan's confirmation regarding why they needed that depth (turn 69). Susan interrupted Aiesha to ask for her opinion on the matter (turn 70). Koyana and Aiesha replied that they had tried a different vinyl piece that was thicker (turns 71 and 72). In her response, Susan characterized the vinyl cutter as being unpredictable (turn 73). Susan asked about the first letter of the sticker. She also asked if they had inserted the vinyl the correct way (turns 75 and 76). The girls reassured her they did, and Susan then commended them on their problem-solving skills and persistence (turns 77 and 79). After talking to Susan, Koyana, Prisha, and Aiesha returned to the vinyl cutter and began working on the sticker Prisha wanted to print next.

4.2. Interpreting "Getting the cut depth right"

What makes this episode illustrative is the ordinariness of the way that the failed sticker print was handled by the students without the teacher's help. While the cutter was still running, Koyana observed that the blade was not cutting deeply enough. To her, it seemed apparent that Aiesha's sticker would fail (line 25). After Prisha stopped the cutter and was inspecting the failed sticker (turns 26 and 32), Koyana suggested that they should set the blade depth one step deeper to nine (turn 33). Prisha agreed and made the adjustment (turns 34 and 35). All this occurred in less than 35 s, one-third of which was spent waiting for the cutter to return the sticker (turns 27–31). In other words, the failure was speedily resolved, and it did not halt the girls' progress with the challenge. The girls' earlier experiences with the cutter seemed to facilitate this process (turn 8). Their initial blade depth, which was eight, might also be an indication of prior learning. The challenge instructions advise the students to use blade depth one on the first level. Although we do not have direct observations from their earlier work, it is a reasonable inference that they might have encountered similar problems the previous time they worked with the cutter and learned that depth eight was most appropriate for the challenge.

The role that the teacher played in responding to the failure is also relevant in this episode. Although Susan did not directly take part in the problem solving, her actions were nonetheless important. She effectively highlighted and acknowledged the students' persistence and problem-solving skills when working with a somewhat temperamental machine that was not easy to operate reliably (turns 77 and 81). In effect, she attributed the cause of the failure to the vinyl cutter rather than to the students or their design. She also positioned the students' actions as skillful and persistent.

4.3. Example 2 Derek's lenses are not level

This example involves Derek, a 6th grade student who was completing his second year of FUSE. At the beginning of the term, Derek worked on a few different challenges, but during his 10th FUSE session that year in mid-October, he decided to return to Eye Candy, a challenge he had worked on the previous year but had not completed. Eye Candy is a 3D printing challenge that asks students to design and print their own plastic eyeglass frames. The challenge consists of three levels, which instruct the students regarding how to use their favorite eyewear design as inspiration to create their own design using SketchUp, a 3D modelling software and the 3D printer in the FUSE Studio. Although Derek had worked on the challenge the year before, he spent 33 studio sessions (~24 h, or ~60 % of his FUSE time) working on his design and eventually printed seven different versions of his glasses before creating a version that was both functional and that satisfied him aesthetically.

The episode we selected to illustrate the second type of failure identified from our data took place at the end of Derek's 16th FUSE session while he worked on Eye Candy. He worked on level one and attempted to print his eyewear, but the print failed. Derek then analyzed the issue with Susan and José, another student, and discovered a flaw in his design. Derek did not have time to fix the issue immediately, but discovering the flaw eventually led him to a solution during later FUSE Studio sessions.

At the beginning of the FUSE Studio session, Derek readied his design for the 3D printer and began the printing process. While waiting, Derek worked with another student, José, on a different challenge; however, something went wrong with the printing process. Their teacher, Susan, walked by the printer and noticed the problem and then called Derek over to the printer (Fig. 3, turns 1 and 3). When Derek arrived, he looked at the printer and noticed that the print was not correct (turns 5 and 7).

Over the next three minutes, Derek, Susan, and José inspected the failed print and created alternative explanations for why it was incorrect. Derek began this line of inquiry by asking aloud, "*What the heck is wrong with it? Come on, really? I hate when this happens*" (turn 11). Susan asked if Derek was the first to use the printer, indirectly suggesting that the failure was caused by a set up issue with

Turn	*Speaker*	*Turn-at-talk / action*
1	Susan:	Derek!
2	Derek:	Yeah! Is it almost done?
3	Susan:	You need to come over here.
4	Derek:	Alright. It said 30 minutes on it. What's up? (said while walking to the printer)?
5	Derek:	It's almost done? Oh!
6	Susan:	Only 32 percent.
7	Derek:	(unclear) Oh God! It is messing up. Can we stop it? It's like jacking it all up Look at all that.
8	Susan:	Yeah I know. That is why I was like you should come back and look and see.

Fig. 3. Something wrong with the printer.

Turn	*Speaker*	*Turn-at-talk*
66	Derek:	Ok, so let's see here. Is everything connected is what I'm wondering. Ok (rotates). Ahaa! That's the problem. Ok, ok. Hold on. Is this connected to that one?
67	Derek:	Ok, that's connected. That is the problem right there. Right there. Problem found. It's right there (sigh). It's not good at all buddy. A lot of problems, a lot of problems wrong with it. I gotta raise this back up, raise this back up. That is better. There. And then this.

Fig. 4. Getting it right.

the printer. Derek did not know, and after he stopped the 3D printer, Susan and Derek inspected different parts of the partially printed frames (i.e., differences in the surface of the print) and discussed how they might locate the cause of the failure. Susan then asked Derek again why he thought the print had failed. In her question, Susan also suggested that Derek´s design might have caused the issue. Derek replied that he did not yet know but thought that two causes were probable: *"I dunno yet. I put it… it's probably something with the makerbot* (3D printer) *'cos it put it to scale. I dunno. I must have done something wrong on it. Either that or the printer just like (went) wacko like it usually does"* (turn 42). This led Derek, Susan, and José to share observations regarding how the print had progressed and to further speculate that the 2D design of the eyewear was the underlying cause of the failure. When leaving the printer to return to his computer station, Derek said, *"Yeah, I dunno. I got to readjust it, then"* (turn 55).

After he returned to the computer, Derek opened his eyewear design in Sketchup and began inspecting his design. While rotating his model, Derek talked aloud to himself and discovered what had gone wrong (Fig. 4, turns 66 and 67).

The rotation revealed to Derek that the lenses of his design were not on the same level (see step 1–4, Image 2). This explained why the print had been incorrect. The printer had attempted to print one side of the eyewear on the print platform and the other above it without any support structure. While rotating the design, Derek discovered other smaller issues and attempted to fix them. The underlying major design issue of leveling the lenses remained unsolved, because his class had to leave for their next lesson before he could proceed. As he prepared to leave, he approached Susan and shared his insights into what the problem might be (Fig. 5, turns 78 and 80), and Susan praised him for finding a potential solution (Turn 81).

4.4. Interpreting "Derek's lenses are not level"

The reason this episode, and Derek's case in general, is illustrative is because Derek's failure led him to learn something new about his design. In short, after his print had failed, Derek collaborated with others to analyze the problem and to generate two competing explanations for its cause, and he identified the underlying issue by returning to his design with the potential explanations, which then placed him on a path to solving the problem. During this process, Derek positioned himself in relation to the failure in several ways. Derek was clearly surprised and frustrated by the fact that the print had failed (turns 7, 9, and 11). Nevertheless, he continued to work on the design to solve the problem. Specifically, Derek was the first to suggest aborting the print (turn 9) as well as the one who initiated the analysis of the problem (turn 11). Derek also viewed the reason for the failure as something that he did not fully understand now (his "yet" in turn 42) and charged himself with making edits to the design (turn 55). Finally, he identified the potential cause of the failure (turn 66).

The way other people in the episode positioned Derek in relation to his design and the failure is also important and suggestive of the culture of FUSE Studios. Susan's actions as the studio facilitator were especially important. At the beginning of the episode, Susan raised a potential issue with the 3D printer with Derek by calling him to the printer (turns 1 and 3). When he arrived, she let Derek

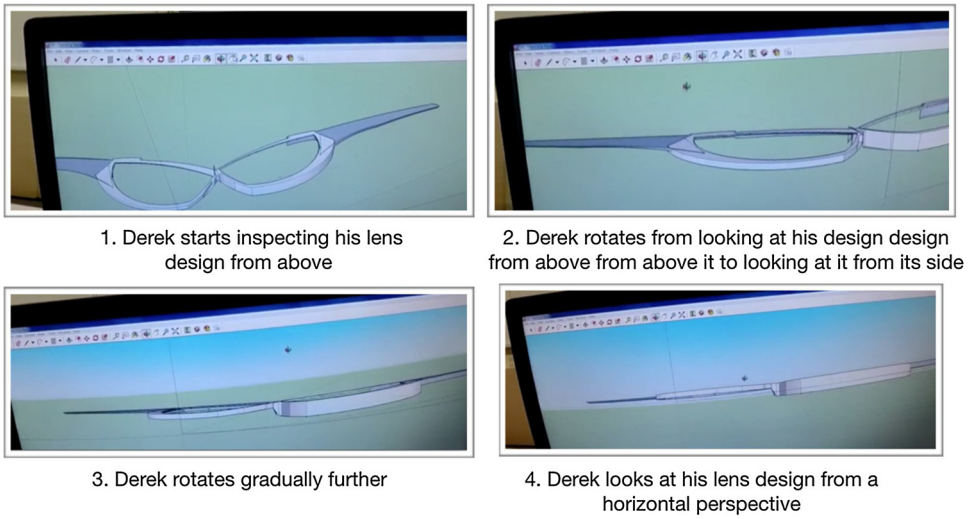

Image 2. Derek's lenses.

Turn	*Speaker*	*Turn-at-talk*
78	Derek:	One side was uneven to the other. So, like this one was a little thicker than this one.
79	Susan:	And do you think that might be a problem?
80	Derek:	That's probably what the problem was.
81	Susan:	Was that's pretty fast if you figured it out that quick.

Fig. 5. Telling Susan.

first inspect the print and then agreed with him that something was wrong with the print (turn 8). Effectively, this positioned Derek as the person who was in control of the printing process and as the rightful agent to determine whether the print was proceeding correctly. Later, while analyzing the aborted print, she continued to position Derek as the main author of the process (e.g., "What do you think?" turn 14). In sum, her actions were supportive of Derek's persistence with the challenge despite the failure, and she positioned him to learn from failure without taking control of *his* process of problem solving.

RQ2. How do participants recognize learning from failure and persistence as significant parts of their FUSE Studio experiences?

Regarding the second research question, analysis of the participant interviews revealed that students recognized failure and persistence as part of their FUSE Studio experiences. All the students we interviewed discussed being persistent with the challenges they completed. For example, they said that at times, they needed to try multiple times before getting something right during the challenge and had to return to challenges they had not been able to complete. They also mentioned that they needed to try different strategies and to consider the challenges and problem solve when stuck on the challenges. Some even mentioned that being persistent with a challenge led them to improvise and to be more creative. Nearly all students reported that the challenges were difficult; at the same time, those same students almost without exception also reported that they found the challenges fun. When asked in interviews about what advice they might give a student new to FUSE, students often said that new students should remember to be persistent when the challenges become difficult. The interview quote below from the student Judy's interview exemplifies the students' perspective regarding being persistent in FUSE.

Student perspectives on learning from failure
INT: So, I'm kind of new to all this and I don't know a lot about FUSE. Can you tell me about it?
Judy: It's fun. You have different challenges and you try to solve them. It's hard. You need practice. You have level one level y*ou have different levels and it starts out easy and it gets harder and harder. But you persevere through it and it's fun, I guess.* (italics added).
INT: I'm confused. You said it's fun and it's also hard.
Judy: It is.
INT: Can things that are fun also be hard?
Judy: Yeah.
INT: How does that work?
Judy: Well, it's fun and it's hard. It's fun, like you're having fun while doing it, but you get kind of frustrated, but then you solve the problems and you persevere through it. (italics added).

In the quote, the interviewer asked Judy to explain the FUSE Studio because he did not know much about it (an interviewing device to elicit a description). Judy stated, specifically in the italicized sections, that as the challenges become difficult, one must persevere through them. For her, this is not just a process of problem solving, but also of working with the emotions related to trying to accomplish something that is difficult. Although the process is fun, it is also frustrating and hard. What Judy in effect said was that completing a level means also working on the problem, even though your in-the-moment emotions might tell you otherwise that you are not progressing.

In relation to learning from failure, another student, Melissa, specifically mentioned the learning potential that failures in challenges offer. In the interview quote below, Melissa briefly discussed this when answering the interviewer's question about what she remembered learning in the FUSE Studio that year. Melissa explained a challenge called "3D You" and a part of the challenge which had proved to be particularly difficult for her. In the italicized section, Melissa highlights the learning potential embedded in failure for her. Importantly, although her answer is framed by her experience with "3D You", at the end of her reply she talks about learning from failure in more general terms as something that is present each time you make a mistake. For her, successful failure is not only associated with the challenges or the FUSE Studio, but also with other activities in her life.

Student perspectives on learning from failure
INT: What things do you remember learning in FUSE?
Melissa: 3D You, I remember that. At first you do everything on the computer, there's a dummy you have to trace, but then that goes. Later in the next level you have to do it with yourself. If there isn't anyone helping you, you have to click the computer, turn around really slowly, wait until you get everything. I don't know the word, but, to… your face characters and all that. So, if you mess up, you have to start all over, which is hard but it's part of the challenge you have to complete. *It's still fun for me. If you do something wrong, you learn from it and you do it better.* (italics added).

During the teacher Susan's interview, the themes of learning and failure were also present. In her interview quote below, Susan describes how working in the FUSE Studio impacted the ways her students learned how to handle failure in addition to problem solving, helping, and collaboration. After the interviewer interpreted her answer, she explained that failing should lead to trying

again and not giving up.

Teacher perspective on learning from failure
INT: Has FUSE had any other impact, any other effect beyond that they've learned problem solving or learned to help or collaborate?
…
Susan: You might fail. (laughter). So that's another thing. Like you might fail and it's not the end of the world.
INT: Yeah so coping with that?
Susan: Yeah, so I guess coping with that and figuring it out again. Hopefully not giving up you know and that sense of trying.

Uncovering the learning potential of failure was not just an outcome that her students achieved by coincidence. For Susan, it was also an explicit goal of her FUSE Studio. In the italicized sections of the quote below, Susan expressed that she wanted her students to learn that mistakes were a source of learning, know-how her students would also need outside the FUSE Studio. Importantly, from her facilitator perspective, Susan positions this goal as an experience her facilitation aims to elicit in her students, but not enforce. For her, learning from failure and getting a sense of worthwhile perseverance were important experiences in the FUSE Studio, but experiences open to her students only if they really tried.

Teacher perspective on learning from failure
INT: Thinking about the big picture, what are your goals for your students in FUSE?
Susan: *My goal is for them to take away the skills needed, besides what they need in FUSE. Like for example, that the mistakes you know they are going to make mistakes but to learn from them* (italics added). That's why they're going to make mistakes and a challenge might be hard, but I really like it to see if they can still try to problem solve and figure down they're like, "Oh, let's open this challenge, I'm done." You know. My goal is not to see all of that. Yeah you can probably take a break, I say take a break then from the challenge if you need to but my goal really was to hopefully *see if they can have that perseverance and really try to finish that and feel that success too because I want them to feel that success* (italics added).

RQ3. How do the interactions in the FUSE Studio impact the teachers' perceptions of their students, if at all?

In relation to our third research question, we found that the way in which Susan saw her students was impacted by her interactions with those students in the FUSE Studio. In her interview Susan talked explicitly about the contrast between how some of her students were conducting themselves during the FUSE Studio sessions and their engagement in her own regular classroom instruction. She reflected that seeing students being different in the FUSE Studio, in comparison to other classes, were moments that remained with her in a positive way. When asked for specific student stories she remembered from the year, she said that she remembered students displaying leadership skills and self-confidence. When talking about Kovana, one of the students represented in example 1, she said that in FUSE, Kovana had been a leader for the other students and that she was more outgoing, talkative, and showed more initiative when working with classmates in the FUSE Studio. Susan also said that she had seen her students be more independent, persistent, and confident in their own abilities elsewhere in school. Regarding Derek, the student represented in example 2, Susan said that in other classes he is, in her words, *"a rusher"* and mainly does things in other classes for grades. In contrast, in FUSE, Susan recognized Derek's persistent engagement with his eyeglass frame design. She also commented on José, the boy helping Derek in example 2, who she saw as becoming the go-to expert and helper in their FUSE Studio, a quality she had seen in other classes but not so dramatically as in FUSE.

In addition to seeing her students differently, Susan also talked about how she had learned to interact differently with them. When talking about their time in FUSE that year, she said that in she had learned to "*let go" and "step back."* For her, this meant letting go of a more traditional teacher-centered role and not trying to control the students' learning. In the italicized section of the interview transcript below, she talks about how her relationship with students has changed, is more open, and how she likes this alternative way of relating with students and wishes it for her teaching in her 'regular' classroom.

Teacher perspective on the value of student-teacher relationship
INT: Where is the value in that?
Susan: The students learn new skills, more that leadership role. *I think it also develops that relationship between the student and the teacher even more. They don't see me as just that authoritative figure. That it opens more lines of communications* when you're just not up there just regurgitating and telling them things all the time. I do like that. That's something you'd always want to strive in your regular homeroom classroom.

Taken together, our results highlight that failure was a significant aspect of the FUSE Studio experience for the students and their teacher. Importantly, this experience not only impacted how the students came to value being persistent and learning from failure but also offered an opportunity for their teacher to view her students in new, arguably more productive, light.

5. Discussion

Although research on the benefits of failure for classroom learning and its conditions has advanced significantly over the past decade, the perceptions and consequences of failure in most schools remain stubbornly resistant to change. Our study presented one approach to reframing failure in schools—the FUSE Studio model, which has that "failure is just another try" among its key design principles. The enactment of that principle in FUSE Studios involves reframing failure for students and teachers alike as an experience

generative of new ideas, ideas generated as students learn to persist. In line with findings in Gomoll et al. (2018) study, our analysis of one typical FUSE Studio showed that failure was both an ordinary, commonplace phenomenon as well as a source for ongoing learning. Our analysis also showed that recognizing the importance of persevering through the challenges was a significant part of the student experience in the FUSE Studio. Here our results resonate with those of Estabrooks and Couch (2018) and point to how open-ended, student-directed making activities can foster the students' own understanding of the generative qualities of failure. Furthermore, our results also showed how the facilitator of the studio recognized increased perseverance as one of the learning outcomes for her students. We believe that by making failure an ordinary and recognizably productive aspect of the educational experiences of the students and teachers alike, the FUSE Studio model demonstrates one way failure could be brought into the routine practices of schools.

An important remaining question is whether such change can be sustained in schools? FUSE Studios are typically something like islands within the normal, operative instructional logics of schools. Could the visibility of failure's ordinary generativity for students and teachers alike find its way into broader school cultures? In the case of Susan, the teacher we've written about in this paper, our findings suggest the former. Her two years of experience with the FUSE Studio model seemed to shift her views of students and their capacities, and seemingly, how she interacts with her students outside the FUSE Studio.

In our other on-going investigations (Stevens et al., 2018) we see similar impacts. Teachers in the traditional academic subject courses often state that they see that they can offer more choice to students. Teachers also talk about 'stepping back' and letting students guide classroom activity. In Susan's case we cannot be sure which way the causal relationship goes. Perhaps Susan was impacted by the interactions with her students in the FUSE Studio or, alternatively she already harbored non-deficit views of students and the FUSE Studio provided an environment for those views to find aligned expression. But both interpretations offer hope regarding broader changes in schools. On one hand, bringing new experiences like the FUSE Studio to schools can change the view of administrators, teachers, and students alike. On the other hand, the FUSE Studio can offer teachers and administrators who are already inclined toward an alternative to the conventional model a real and sustainable option that 'fits' into the school day as a class. Whether these are movements toward the structural changes that Varenne and McDermott (1999) envision for American schools remains to be seen and investigated. However, a sustainable island that enacts failure, and therefore success, differently in schools is at least a start.

Our results also offer a potentially important caveat regarding the productive failure model (Kapur, 2008). While this study focused on a particular aspect of the FUSE Studio model—making failure just another try—our results highlight that this principle seemed to work in concert with other equally important principles (Stevens et al., 2016). Derek's case is illuminating in this regard. For Derek failure was not productive solely because his failures led to improvements in his design. For this to happen, it seemed necessary for Derek to be able to choose that particular challenge and thereby form a personal commitment to overcoming failure. This aspect of choice in the FUSE Studio was commonly mentioned by other students in their interviews, who stated that they often returned to unfinished challenges during the year, even after starting a new line of work on new challenges. Furthermore, what also facilitated Derek's commitment to his eyewear design was the lack of completion requirements and formal assessments in the FUSE Studio. It therefore seems that while one design principle might directly address a change that is needed, the potential effects of this principle are not separate from the whole set of interoperating principles. This observation seems important if we want failure to become an active resource for learning in schools, especially from the students' perspective. While the productive failure model (Kapur, 2008) offers one way for teachers (and administrators) to foster students' effective learning of canonical solutions in science and mathematics, it might not be a sufficient solution for students to learn to appreciate the general, transferable value of failure. Our results suggest that more is needed. In addition to having the opportunity to fail repeatedly and to have related instruction, failing should also need to be relatively cost-free and students should have the option to choose to re-engage with the tasks or activities they initially failed at, if they wish to do so. This way, the productivity of failure might become an active resource not only for the Edisons of our time, but for all students.

6. Statement

This manuscript has not been published elsewhere and has not been submitted simultaneously for publication elsewhere.

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